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PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

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WILLOW CREEK BASIN

WEST McCARTER DAM
MT-397

NORTH McCARTER DAM
MT-398

PREPARED FOR:

THE HONORABLE TED SCHWINDEN
GOVERNOR OF THE STATE OF MONTANA

WILLIAM McCARTER
(OWNER AND OPERATOR)

PREPARED BY:

MORRISON - MAIERLE, INC.
CONSULTING ENGINEERS

JULY 1981

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EXECUTIVE SUMMARY

Under contract with the State of Montana Department of Natural Resources and Conservation and with representation from Department of Natural Resources and Conservation and Mr. William McCarter, Morrison-Maierle, Inc. inspected the McCarter Dams on 28 August, 1980 under the authority of Public Law 92-367. The dams are located on Willow Creek, a tributary to the Tiber Reservoir and Marias River in Toole County about three miles northwest of Galata, Montana.

The report was compiled from information obtained during onsite inspection and analysis of available information. Findings were compared with engineering criteria that are currently accepted by most private and public agencies engaged in dam design, construction, and operation.

FINDINGS AND EVALUATION

McCarter Dams are owned and operated by Mr. William McCarter and the reservoir is used solely for storage of irrigation waters. The project consists of two main embankments connected by a dike. The west embankment and dikes, oriented generally north-south, is 2020 feet long and 30.5 feet high at its highest point. The northern-most point of the west dike intersects natural ground. The north embankment and dike, oriented generally east-west, is 2180 feet long and 44 feet high at its highest point. The western-most point of the north dike meets the west dike where they both intersect natural ground (See Plate 3). The composite earthfill embankments, constructed without engineering investigation or design, impound 7000 acre-feet of water at the minimum dam crest elevation 3113.0 feet, National Geodetic Vertical Datum (NGVD). All elevations used in this report are based on assumed elevation 3110.0 feet NGVD at the top of the west outlet pipe gate.

Based on criteria in U.S. Army Corps of Engineers Recommended Guidelines for Safety Inspection of Dams (Reference 1), the project is intermediate in size. The dams are located such that its failure would not endanger inhabited structures but would cause significant economic loss. Downstream from the dams there are no residences; only a railroad, two county roads and U.S. Highway 2 would be affected by a sudden dam failure. Flood water would be received and routed by Tiber Reservoir 8 miles downstream. No dam breach analysis or routing of a dam breach flood was made for the downstream area and the conclusions on probable damage are based on a brief field visit and engineering judgement.

The project is classified as having a significant downstream hazard potential (Category 2). Inspection criteria (Reference 1) recommends that an intermediate size project with a significant downstream hazard potential be capable of safely handling a flood in the range of one-half the probable maximum flood (PMF) to a full PMF. The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region. Based on the finding of this inspection, one-half the PMF is recommended as the spillway design flood (SDF) because of the low risk to inhabitable structures located downstream and potential for economic loss.

An estimated probable maximum precipitation (PMP) was developed for the 463-square mile drainage basin. The PMF resulting from a 72-hour PMP has an estimated volume of 257,000 acre-feet and a peak flow of 195,000 cfs. The project has no spillway and the combined capacity of the outlet works is 725 cfs with the reservoir at the top of the dam, elevation 3113.0 feet NGVD. Because the capacity of the outlets is negligible compared to the PMF flow, the project essentially provides no routing of high flood flows. A flood having a volume of 3% of the PMF would cause the reservoir to overtop the embankment even if the reservoir was empty at the beginning of the flood. The dams are constructed of materials that would quickly erode and rapidly fail when overtopped by floodwaters. Such failure would not endanger inhabited structures but could cause significant damage to a railroad, U.S. Highway 2 and two county roads.

The north embankment of the dam overtopped and failed in 1955 sending a "wall of water", as reported by a local resident, down the Willow Creek channel. No residential structures were affected by the flood wave and the bridge on U.S. Highway 2 was overtopped but not washed out.

The existing dam crest elevations are greater than the dam which failed in 1955. Therefore, the existing dams have a greater storage potential and an overtopping failure during a large flood event could be more severe than the 1955 failure.

There are no piezometers or other instrumentation in the dams and available information is not adequate to determine embankment stabilities.

Based on the field inspection and study of hydrologic data, it was determined that McCarter Dams do not conform to the inspection guidelines with respect to discharge and/or storage capacities to safely handle the recommended spillway design flood.

RECOMMENDATIONS

A downstream warning system for use in the event of possible dam distress needs to be developed and placed in action. Repair wave eroded scarps on the upstream slopes and protect the embankments with riprap. Repair local areas of gully erosion on the downstream slopes and remove sediment from against the west outlet control gate to assure that gate is operational.

Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate. Determine the phreatic surface by installation and monitoring of piezometers and perform a slope stability analysis of the embankments using field exploration and laboratory testing of foundation and embankment soils. The dam should be inspected at no longer than 5-year intervals by engineers experienced in dam design and construction.

MONTANA
RODGER C. FOSTER
3654 E
REGISTERED PROFESSIONAL ENGINEER

PERTINENT DATA
McCarter Dams

1. GENERAL

Federal ID No.	West McCarter Dam	MT - 397
	North McCarter Dam	MT - 398
Owner		William McCarter
Operator		William McCarter
Date Constructed		1952-1953
Location		Section 19, T32N, R3E Section 24, 25, T32N, R2E Principal Meridian; Latitude 48°30'20" Longitude 111°24'20"
County, State		Toole County, Montana
Watershed		Willow Creek
Size		Intermediate
Downstream Hazard Potential		Category 2, Significant
USGS Quadrangle		McCarters Lake, MT

2. RESERVOIR

Surface Area at top of dam (Elevation 3113.0 feet NGVD)	960 acres
Drainage Area	463 square miles
Storage at Normal Pool (Elevation 3100.0 feet)	1400 acre-feet
Storage at Dam Crest (Elevation 3113.0 feet)	7000 acre-feet
Surcharge Storage	None

3. SPILLWAY — There is no spillway for the project.

4. OUTLET WORKS

4.1 North Outlet Conduit	60-inch diameter corrugated metal pipe
Conduit length from intake to outlet	170 feet

Control gate	60-inch diameter slide gate
Capacity with Reservoir at Dam Crest (Elevation 3113.0 feet)	450 cfs.

4.2 West Outlet Conduit

	84-inch diameter corrugated metal pipe
Conduit length from intake to drop structure	58 feet
Control Gate	84-inch square vertical slide gate
Drop Structure (at outlet)	84-inch diameter corrugated metal pipe set vertically with a 30-inch x 72-inch rectangular discharge opening.
Capacity with Reservoir at Dam Crest Elevation (outlet orifice control)	280 cfs

5. DAM

5.1 North Embankment

Type	Composite Earth Fill
Length	2180 feet
Crest Breadth	17 to 20 feet (varies)
Crest Elevation	Varies 3123.5 feet NGVD to 3117.0 feet NGVD
Hydraulic Height (minimum crest to toe)	38 feet
Maximum Height crest to toe	44 feet
Upstream Slope	1V on 1.4H to 1V on 1.5H
Downstream Slope	1V on 1.4H to 1V of 1.5H

5.2 West Embankment

Type	Composite Earth Fill
Length	2020 feet
Crest Breadth	17 to 20 feet (varies)
Crest Elevation	Varies 3115.5 feet NGVD to 3113.0 feet NGVD
Hydraulic Height (minimum crest to toe)	28 feet
Maximum Height crest to toe	30.5 feet
Upstream Slope	1V on 1.4H
Downstream Slope	1V on 1.4H

Chapter 1
BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of McCarter Dams, owned and operated by Mr. William McCarter of Galata, Montana.

The National Dam Inspection Act, Public Law 92-367 dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-Federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' report to the United States Congress on "National Program of Inspection of Dams" in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many Federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary, the guidelines recommend a two-phased study procedure for investigation and evaluation of existing dam conditions, so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam.
(2) based upon an evaluation of the available data and a visual inspection.
(3) performed to determine if any needed emergency measures and/or if additional studies, investigations, and analyses are necessary or warranted.
(4) not intended to include extensive explorations and analyses or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses, and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally-owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases, the Corps may proceed with Phase II studies but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigation outlined above are intended only to evaluate project safety and do not encompass in scope the engineering

required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and no action or failure to act under this Act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify conditions that threaten public safety, so that they may be corrected in a timely manner by non-Federal interests.

1.1.3 Inspection

The findings and recommendations in this report are based on a brief visual inspection of the project conducted on August 28, 1980 and discussion with Mr. McCarter. Inspection procedures and criteria are those established by the Recommended Guidelines for Safety Inspection of Dams (Reference 1).

Personnel present during the inspection included:

Larry Tegg	Dam Safety Engineer, State of Montana, Department of Natural Resources and Conservation
Rodger Foster	Team Leader, Morrison-Maierle, Inc. Water Resource Engineer
Mike Kaczmarek	Engineering Geologist, Morrison-Maierle, Inc.
William McCarter	Owner

Mr. McCarter accompanied the team on the inspection and provided much background information on the history of the project.

Additional Morrison-Maierle personnel who contributed to the evaluation are:

Bill Keith	Structural Engineer
Ken Salo	Hydrologist/Hydraulics Engineer.

This report has been reviewed by the Montana Department of Natural Resources and Conservation and the owner. The owner did not respond.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

The McCarter Project is an irrigation storage project located on Willow Creek and tributary to the Tiber Reservoir. The dams are located entirely on Mr. McCarter's property approximately three miles northwest of the town of Galata, Montana in Toole County (Plates 1 and 2). As shown on Plate 3, the project consists of two embankments connected by a dike and impounds 7000 acre-feet at the dam crest elevation 3113.0 feet. The hydraulic height of the west embankment is 28 feet and the north embankment is 38 feet. All elevations in this report are based on an assumed project datum determined from a USGS quadrangle map which correspond to the National Geodetic Vertical Datum (NGVD). No project datum has previously been established.

The Federal identification number for the West McCarter Dam is MT-397 and for the North McCarter Dam MT-398. The project controls releases to Willow Creek. Based on visual reconnaissance and engineering judgement there is one railroad, U.S. Highway 2, and two county roads which would be affected by a sudden breach of the dams. There are no inhabited structures downstream of the McCarter Dams which would be affected. Water from a dam breach would be received by Tiber Reservoir located approximately 8 miles downstream. On the basis of this information and in accordance with recommended guidelines, the dams are classified as intermediate in size and the downstream hazard potential is significant (Category 2).

The project consists of two dams, a north dam and a west dam, connected by a dike (Plate 3). The crest of the dams and dike are irregular with the low point of the project embankment, elevation 3113.0 feet NGVD, being located in the dike where it meets natural ground at station 21+81. The north embankment is located across Willow Creek and the west embankment is placed across a small tributary. A low divide in the topography separates the project into two reservoirs until the water surface reaches elevation 3110.5 feet. Then a transfer between the reservoirs will eventually equalize the water surface.

There is no spillway for the project. All primary releases from the reservoir are controlled by two gated outlets, one located in each dam embankment. The north low level outlet consists of a 60-inch diameter, corrugated metal pipe controlled by a slide gate. The west outlet is located near the south abutment at a higher elevation than the north outlet. The west outlet consists of an 84-inch diameter, corrugated metal pipe which drops into a vertical pipe section of the same diameter. Flow discharges through a 30-inch by 72-inch rectangular opening in the side of the drop pipe. Inflow to the pipe is controlled by an 84-inch square vertical slide gate mounted on the pipe entrance.

1.2.2 Regional Geology and Seismicity

The McCarter Dams are located in the Northern Great Plains physiographic province (Fenneman, 1931, Reference 2). The area is characterized by gently rolling terrain of low hills and broad shallow depressions and drainage swales. Stream valleys are trenched into the rolling upland surface to form a well-integrated drainage system exhibiting a dendritic pattern.

The bedrock that underlies McCarter Dams and most of the surrounding area is the Colorado Shale of Cretaceous age. Other consolidated sedimentary formations present to the east of the dam sites are, in ascending order beginning at the top of the Colorado Shale, the Telegraph Creek Formation, the Eagle Sandstone, the Clagget Shale, and the Judith River Formation. The bedrock formations dip eastward at about 35 feet to the mile away from the Sweetgrass arch (Smith et al, 1959, Reference 3). Several small open synclinal and anticlinal structures interrupt the regional dip (Erdmann, 1948, Reference 4). Regional faults have not been detected in the area near the McCarter Dams although thrust faulting is reported (Pierce and Hunt, 1937, Reference 5) about 50 miles to the east.

The north-central plains region, including the Willow Creek drainage, is covered with glacial drift of at least two independent ice advances into the area. The glacial drift deposits include unstratified till, end and recessional moraines, ablation moraines, and stratified to unstratified kames, eskers, and other minor ice-contact deposits. Other glacial deposits are outwash channels and terraces.

McCarter Dams are located in seismic probability Zone 2 as defined by the U.S. Army Corps of Engineers in "Recommended Guidelines for Safety Inspection of Dams" based on work by Algermissen and Perkins (1976, Reference 8). The seismic probabilities used herein divide the United States into four seismic risk zones based on the record of the severity of shaking and the reasonable expectancy of earthquake damage. Seismic probability or risk in Zone 2 indicates that moderately destructive earthquakes may occur. Zone 2 corresponds to a potential intensity of VII on the Modified Mercalli intensity scale of 1931.

McCarter Dams and the surrounding area are within a region where the shock waves from major earthquakes that occurred elsewhere were felt. However, there is no record of earthquake activity originating at or near McCarter Dams. The potential for displacement of the foundation materials is negligible with no evidence of a fault or fault trend present in the foundation. Under the Recommended Guidelines, dams in Seismic Zones 0, 1, and 2 may be assumed to present no hazard from earthquake loading provided the dams can be shown to be stable under normal operational loads and acceptable safety margins exist.

1.2.3 Site Geology

Willow Creek at McCarter Dams and the stream valley downstream from the project are generally congruent with a contact between two ages of glacial till. The younger till is on the west side of the stream. The stream valley and its attendent terraces appear to closely follow what is interpreted to be an ice-contact position along the eastern margin of the younger till. The width of the Willow Creek valley and the valley margin terraces is roughly 9000 feet at the location of McCarter Dams.

Three terrace levels are evident at the dam sites including the present physiographic flood plain of Willow Creek. The uppermost terrace level is about elevation 3120 or slightly higher. The intermediate terrace level is elevation 3090 to 3105 and forms a nearly level, dissected alluvial valley floor into which the present physiographic flood plain terrace level of Willow Creek is incised about 15 feet to elevation 3075 at the dam sites.

The elevation 3120 terrace is interpreted to be a kame terrace deposited in an ice marginal channel. The elevation 3090 to 3105 terrace is roughly 2500 feet wide at the dam sites and is considerably oversized for the modern Willow Creek channel. The oversized width of the alluvial valley at elevation 3090 to 3105 suggests the terrace represents a melt water channel downcut below the level of the kame terrace. The present Willow Creek channel at elevation 3075 is incised into the melt water channel, ranges from 100 to 200 feet wide, and meanders the full width of the oversized melt water channel.

The McCarter Dams are located entirely within the terrace deposits of the Willow Creek valley. A bedrock ridge of Colorado Shale protrudes discontinuously through the terraces in northwest to southwest alignment from the northwest corner of section 24 to about the center of the SE ¼ section 24 where Colorado Shale bedrock is visible in the dike foundation at an angle point (station 21+81 on Plate 3).

The terrace deposits consist of unconsolidated clay, silt, sand and gravel. The upper portions of all the terraces tend to be fine grained materials including plastic clay, sandy silt, and very fine grained sand. The terrace materials tend to become coarser grained with increasing depth and the meltwater terrace at elevation 3090 to 3105 contains considerable coarse sand and some gravel lenses in contrast to the fine grained sand and clays of the elevation 3120 terrace. The limited exposures of Colorado Shale consist of weathered black fissile clay shale. Glacial till is not exposed at the dam sites.

The materials exposed in a wave cut bench scarp on the upstream face of the left abutment near station 0+00 (Plate 3) consist of a dark gray, flat bedded, heavy plastic clay about 10 feet or more thick. The clay contains a few sandy stringers; scattered rounded pebbles of quartzite; scattered angular fragments of a tan, slightly friable sandstone (Virgelle sandstone); and numerous small fragments of black, fossile shale. The clay is highly expansive and exhibits strong vertical shrinkage cracks on about 15 inch spacings. The clay rests on semiconsolidated, friable, tan silt that is exposed at the base of the scarp. The clay is interpreted to be a kame deposit formed in an ice marginal depression between melting glacial ice and the terrain adjacent to the ice. The fragments of black shale, quartzite pebbles and angular sandstone blocks were possibly washed from the ice or from till adjacent to the ice. The clay represents the elevation 3120 terrace deposits at the left abutment.

Most of the foundation materials are covered along the length of the project and could not be inspected. The melt water deposits of the elevation 3090 terrace are exposed in the side of the Willow Creek channel about 100 feet downstream from station 8+50 on the north dam embankment (Plate 3) near the 60 inch outlet pipe. The melt water deposits consist of fine sand containing 2 to 3 inch thick fine pebble gravel stringers all interbedded with silty clay lenses. The melt water alluvium is mostly covered and the length, thickness, and distribution of individual lenses could not be seen. The thickness of the terrace alluvium is unknown.

Black shale bedrock is exposed on the upstream foundation area at station 21+81 (Plate 3) and appears to support much of the foundation under the west dam and dike between stations 21+81 and 42+00. The shale outcrop is a terrace surface at about elevation 3100 under the west portion of the embankment and is incised by two water courses that are probably filled with fine grained alluvium including the areas in the embankment foundation. The right abutment materials resemble glacial till on the weathered and plowed land surface; however, the terrace morphology of the right abutment strongly suggests the clayey abutment materials are the same heavy clay as seen on the left abutment.

1.2.4 Design and Construction History

The McCarter Dam Project was financed and built by the owner without benefit of engineering design or field testing. Mr. McCarter told the inspection team that he had experience in building dams in the 1930s and was knowledgeable in dam construction methods.

The west dam was constructed to its present height in 1952 including the dike which extends to the natural ground at approximate station 21+81 on Plate 3. The north dam was built in 1953 to an elevation approximately equal to the west dam (6 feet lower than the present embankment) and did not include the dike extending to the west. In 1955 the north dam failed by overtopping during a time when the outlet gate was inoperable. The original outlet was a 48-inch diameter concrete pipe conduit which was replaced with a 60-inch diameter CMP when the breach was repaired in 1956. The original outlet in the west dam was also a 48-inch diameter CMP which was replaced with an 84-inch diameter CMP at some later date.

Some time after 1962, Mr. McCarter raised the north dam approximately 6 feet and added a dike to connect the existing west dike with the north embankment. At the point where the two dikes meet at approximately a right angle (Station 21+81) their crests are at the natural ground elevation. The natural high ground upstream of the dikes was lowered 2.5 feet below the crest to provide a flow path between the two reservoirs.

No spillway was ever constructed for the project because the owner felt the storage capacity of the reservoir and the combined capacities of the 60-inch and 84-inch outlets would be sufficient to route large floods. The owner also stated that by raising the north dam above the adjacent dike, he essentially has prevented that dam from being overtopped again by forcing flood water to overtop the dike instead.

CHAPTER 2

INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillway

The McCarter Project has no spillway.

2.1.2 Outlets

2.1.2.1 North Dam Outlet.

The low level outlet for the north dam consists of a 170-foot long, 60-inch diameter, corrugated metal pipe (CMP) (Plate 4). The inlet to the pipe is a prefabricated 60-inch CMP section angled at approximately 35° from the horizontal. The pipe is controlled by a 60-inch diameter slide gate located at the inlet with the gate stem extended on the upstream embankment slope to a hand wheel control (Photo 8). The outlet section consists of a flared corrugated metal section (Photo 9) set in concrete which transitions to a 25-foot long concrete apron. Normally the gate is kept closed and is opened only to release water during high reservoir levels and runoff periods.

Visual inspection of the pipe showed it to be in generally good condition. No dents were noted and seepage was minor. Three small holes exist in the east wall of the inlet section from which a visible trickle of water seeps down the pipe (Photo 10). Embankment material exposed behind the hole is solid and no void has been created from piping. Approximately 48 feet from the gate a minor seep has formed near the top of the pipe. Three or four other areas of seepage were observed as evidenced by mineral deposits at the joints (Photo 11). Approximately 1 to 1.4 feet of water stands in the outlet pipe because the elevation of the apron is higher than the flow line of the pipe. Foundation settlement may be the cause for this condition. The invert elevation at the outlet of the pipe is 3080.0 feet NGVD. Flow capacity through the pipe is estimated to be 370 cfs at reservoir elevation 3104.0 feet and 450 cfs at the minimum dam crest elevation 3113.0 feet. The discharge rating curve is presented on Plate 7. The gate was considered closed at elevation 3103.0 feet but fully opened at 3104.0 feet. The pipe was assumed to be flowing full with a Manning's 'n' value equal to 0.024.

A second conduit passes through the north embankment at approximately station 4+00, which is used to irrigate a small piece of ground immediately downstream of the dam. The conduit is a cast iron pipe approximately 6-inches in diameter and is controlled by a gate on the upstream side of the embankment. The outlet is operable, however, the discharge capacity for this outlet was not developed due to its limited capacity. The outlet end of the conduit is not located near the dam embankment and erosion from discharges cannot endanger the embankment.

2.1.2.2 West Dam Outlet

The outlet works in the west embankment (Plate 5) is located at station 38+26 (Plate 3), approximately 310 feet from the south abutment and 675 feet from the approximate center of the west dam. The outlet (Photo 16 & 17) consists of an 84-inch diameter corrugated metal pipe (CMP), 66.5 feet long with an inlet invert elevation of 3103 feet, approximately 10 feet lower than the minimum dam crest elevation. A vertical slide gate (Photo 18) controls the inlet at the pipe entrance.

The outlet works is located in the dike section south of the west embankment and was 9 feet higher than the water surface during the inspection. The slide gate, mounted on the pipe entrance, was silted to within 3 feet of the top of the pipe. The owner stated this was common because of the location of the outlet. The sediment sluices out at first use. The discharge end of the pipe is capped with a steel plate preventing flow out the end. Instead, the bottom has been cut out of the pipe allowing flow to drop into a fabricated drop structure consisting of a vertical CMP of the same size. The vertical pipe is set on a concrete slab and has a 30-inch by 72-inch rectangular hole cut into the side at the bottom through which water discharges. No design plans are available for the drop structure and its stability is questionable. Continued high flows through this pipe could cause erosion problems which would affect the stability of the dike. A large channel (Photo 19) has been eroded downstream of the outlet which joins Willow Creek below the north dam. Estimates of discharge capacity indicates outlet orifice control at reservoir elevations above 3110.0 limits flow to 280 cfs at the dam crest elevation.

A visual inspection was made of the inside of the pipe and it was found to be in good condition.

A second outlet through the west embankment is located approximately 20 feet south of the 84-inch outlet. This second pipe is a 24-inch diameter reinforced concrete pipe with an outlet elevation of 3102 feet NGVD. The inlet is controlled with a vertical slide gate which was buried at the time of the inspection. The embankment at the outlet has eroded, undermining the pipe and causing one section of pipe to break off (Photo 21). Erosion control at the outlet is necessary to protect the embankment from further undermining. This outlet is used infrequently and under normal use does not pose a threat to the embankment.

2.1.3 Freeboard

Because the dam overtops during the recommended spillway design flood (SDF: see paragraph 2.2.4) it has no freeboard. The vertical distance between the low point on the McCarter Dams (elevation 3113.0 feet) and the north and west reservoirs at the time of inspection was 13 feet and 19 feet respectively. The vertical distance between the normal pool of the north reservoir (elevation 3100.0 feet) and the minimum crest elevation of the north dam is 17 feet. The top of an observed wave-cut bench on the north dam is at elevation 3107.0 feet which is 10 feet lower than the minimum north dam crest elevation and 6 feet lower than the minimum dam crest elevation of 3113.0 feet located in the dike between the north and west dams. Prevailing winds in the region are from the west and north and would direct wind-generated waves toward the dams. High water marks on both dams

indicate that the pool has reached an approximate elevation of 3110.0 feet. It is estimated that wave runup on the embankments could exceed 5 feet which would cause the west dam, west dike and north dike to be overtopped if high winds are coincident with a high reservoir elevation. At a normal pool elevation of 3100.0 feet wave runup would not threaten these embankments. It is estimated that the north dam, with 17 feet of vertical distance between normal pool elevation and the minimum dam crest elevation would not be overtopped by wind-generated waves.

2.2 HYDROLOGY, CLIMATOLOGY AND PHYSIOGRAPHY

2.2.1 General

The climate of the area is continental in nature, characterized by warm summers and cold winters. Two climatological stations with good record are located in the vicinity of the McCarter Dam basin. The Dunkirk 15 NNE station with 64 years of record is located 17 miles to the northwest of the reservoir at an elevation of 3380 feet NGVD. Mean annual precipitation at Dunkirk is 10.9 inches with 25% falling in the heaviest precipitation month of June. A mean of 1.6 inches of precipitation or 15% of the annual precipitation falls during the winter months from December to March. Mean annual temperature at Dunkirk is 40.8°F with the mean June temperature of 58.1°F and mean temperature from December through March of 20.8°F.

A second climatological station, Joplin 1N, is located 29 miles to the east of the reservoir near the town of Joplin. The Joplin station is at an elevation of 3360 feet NGVD and has 43 years of record. Mean annual precipitation at Joplin is 10.7 inches with 26% falling in June, the heaviest precipitation month. A mean total of 1.25 inches falls during the winter months from December through March.

Mean annual precipitation in the McCarter Dam basin averages approximately 12 inches. The higher elevations of the Sweet Grass Hills, which comprise less than 20% of the McCarter Dam basin, receive up to 20 inches of precipitation annually. Temperatures would be expected to best compare with the Dunkirk station which is at an elevation equal to the average elevation in the McCarter Dam basin.

The drainage basin for McCarter Reservoir is 463 square miles and is generally shaped like a diamond (see Plate 2) and measures approximately 28 miles (east-west) by 32 miles (north-south). It is located in the rolling plains of northcentral Montana on Willow Creek. The reservoirs natural drainage basin varies in elevation from 3100 feet to 7000 feet NGVD and is covered primarily by short plains grasses. The Sweet Grass Hills are located at the north end of the basin and rise abruptly from the plains to an elevation of approximately 7000 feet. They cover a small percentage of the total basin and the McCarter Dams are separated from the hills by approximately 23 miles of rolling plains.

A small percentage of the basin drains to local potholes and would not contribute to runoff at the McCarter Dams.

2.2.2 Reservoir Storage

The reservoir has a surface area of 960 acres and storage volumes of 7000 acre-feet at the minimum dam crest elevation of 3113 feet NGVD. The storage available between the normal pool elevation of 3100.0 feet and 3113.0 feet is 5,600 acre feet.

2.2.3 Estimated Probable Maximum Flood

The probable maximum flood (PMF) is the flood expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. An estimate of the PMF was made during this dam safety analysis and was routed through the reservoir.

The probable maximum precipitation (PMP) was developed using procedures outlined in the "Interim All-Season Probable Maximum Precipitation Estimates, Missouri River Drainage West of the 105th Meridian," published by the Hydrometeorological Branch of National Oceanic and Atmospheric Administration (NOAA), (Reference 9). The all-season PMP produces 16.3 inches in a 72-hour storm.

The 72-hour storm was broken into 1-hour increments and rearranged in a critical time sequence as illustrated in the Weather Bureau's Hydrometerological Report No. 43 (Reference 10), page 204 figure 6-1e. The hourly increments of the twelve greatest PMP hours were rearranged in the reverse order of the unit hydrograph to produce the greatest possible peak.

A minimum loss rate of 0.15 inches per hour was assumed to represent the hydrologic class B soils in the basin and minimum infiltration conditions due to saturated ground.

A triangular unit hydrograph for a 1-hour duration was developed for the basin, using procedures contained in the Design of Small Dams (Reference 11). The Kirpich equation was used to estimate the time of concentration which equaled 17.5 hours.

The Soil Conservation Service method of developing a curvilinear fit for the triangular unit hydrograph was used. The curvilinear unit hydrograph was divided into 1-hour increments and the PMP was applied by means of the HEC-1 computer program (Reference 12). This estimate of the PMF produced a flood with a peak flow of 195,000 cfs and a volume of 257,000 acre-feet.

2.2.4 Flood Routing

Routing the probable maximum flood through McCarter Reservoir was performed using the HEC-1 computer program (Reference 12). The reservoir was assumed to be at the normal pool elevation of 3100 feet NGVD at the beginning of the PMF. The outlet works on the dams are normally closed and it was assumed that the 84 inch outlet would be fully opened when the reservoir reached its invert elevation of 3103 feet NGVD, and the 60 inch outlet would be fully opened when the reservoir reached an elevation of 3104 feet, NGVD.

The routing shows that the dams will be overtopped during the PMF when three percent of the total flood volume has entered the reservoir. Routings were made of lesser hypothetical floods than the PMF to determine the flood magnitude that the project can control. The hypothetical hydrograph was obtained by applying a percentage to the PMF ordinates. A flood with a hydrograph having ordinates corresponding to three percent of the PMF ordinates is just controlled by the project. Larger floods will overtop the minimum dam crest elevation of 3113 feet NGVD.

2.3 GEOTECHNICAL EVALUATION

2.3.1 Dam

The McCarter Project is approximately 4200 feet long and consists of two embankments; one oriented generally east-west and referred to as the north dam, and one oriented generally north-south and referred to as the west dam (Plate 3). The west dam was constructed in 1952 and consists of a homogenous earth fill. The north dam was constructed in 1953 and failed by overtopping in 1955. The breach was repaired in 1956 and some time after 1962 an additional six feet of fill was placed on the crest of the north dam from about station 00+10 to 10+55 (Plate 3). Thus, the north embankment consists of a composite fill resulting from three separate periods of construction.

The west dam is about 2020 feet long. The grade along the length of the crest is irregular and ranges from elevation 3113 at station 25+92 to elevation 3115.5 at station 36+00 (Plate 3). The width of the crest is about 17 feet and the maximum structural height of the embankment where it crosses a water course at station 31+40 is 30.5 feet. The minimum structural height of the west embankment in about 2.5 feet near station 24+00 and the intersection of the west and north embankments at station 21+81 is in a shallow cut in natural ground. Both the upstream and downstream faces of the west dam slope at 1V on 1.4H. The faces are not dressed and the 1V on 1.4H slope appears to represent the angle of repose of materials side cast onto the face of the embankment.

The north dam is about 2180 feet long as shown by the stationing on Plate 3. The fill added after 1962 extends from station 0+00 to about 10+55. The area breached by overtopping in 1955 as described by Bill McCarter, owner of the dam, was centered on the present 60 inch outlet conduit and was 100 to 200 feet wide with vertical walls. The approximate location of the breach was between stations 7+00 and 9+00. Repair of the breach in 1956 involved laying back the vertical scarps of the breach so that earthmoving equipment could traverse the breached area to place earthfill in lifts aligned with the crest length. The exact length of the repaired section of embankment is unknown.

The crest elevation of the 1955 fill between stations 10+55 and 21+81 ranges from elevation 3115 to 3118.2 feet. The height of the 1955 fill from toe to crest ranges from 6 to 8 feet from station 10+55 to about station 20+50 where the crest elevation drops to meet the juncture with the west dam. The crest elevation of the post-1962 fill from station 0+00 to 10+55 ranges in elevation from 3123.4 to 3122 feet except at stations 0+00 to 0+10 where the crest elevation is 3118 feet. The crest width of the north dam ranges from 17 to 20 feet and the maximum structural height of

the embankment is 44.0 feet. The slope of the upstream face of the north dam is 1V on 1.4H to 1V on 1.5H with the steeper slope located in the 1952 fill from station 10+55 to 21+81. The downstream face slopes at slightly less than 1V on 1.5H in the area of post-1962 fill and slopes about 1V on 1.4H from stations 10+55 to 21+81.

Three borrow areas were used as sources of impervious embankment material. One source is the clay alluvium of the elevation 3120 kame terrace at the left abutment area of the dam in the center of the SW¼, section 19. Clayey colluvium and alluvium were borrowed from the scarp and footslope of the elevation 3120 kame terrace in the NW¼, section 25 and used as fill in the west dam embankment. A combination of clayey kame terrace alluvium and weathered black clay shale bedrock was borrowed from the low bedrock ridge in the reservoir area near the upstream face of the angle point in the dam in the center of the SE¼, section 24. The distribution within the embankment of the soils borrowed from the three different source areas is unknown. The soils all classify as heavy, plastic clay with minor amounts of silt, sand and rock fragment factions (based on field texturing). The embankment fill was placed by means of a crawler-pulled "tumble bug" scraper without roller compaction.

The irregular grade of the embankments crest appear to be the result of the original construction. The crest surface is generally regular and well drained and moderately vegetated with crested wheat grass. The surface of the 1952 portions of the embankment crest display strong shrinkage cracks 18 to 20 inches deep due to dessication of the expansive clay soils. The shrinkage cracks probably swell shut when precipitation or snow melt moisture wets the soil.

The upstream face of the north dam is protected with riprap consisting of cobbles and boulders ranging in size from 6 to 18 inches in average dimension. The cobbles and bolders consist predominantly of rounded quartzite and granitic rocks. The riprap area extends from the left abutment at station 0+00 to station 10+55. The riprap zone was evidently emplaced by dumping it down the face from a truck parked on the shoulder of the dam crest and ranges in thickness from 6 inches to more than 36 inches. A wave cut bench is present at elevation 3107 along the entire face of the dam from station 0+00 to about station 9+90. The bench headscarp is 4 to 6 feet high. Some newer riprap has been dumped over the headscarp of the wave cut bench; however, the present riprap is not adequate to protect the embankment from continuing wave erosion. The remainder of the upstream face from station 9+90 to station 42+00 does not show signs of wave erosion.

The downstream face of the post-1962 portion of the dam from station 0+00 to station 10+55 displays numerous tension cracks and a number of small slump displacements. The tension cracks are 3 to 6 inches wide, parallel to the crest alignment, and fairly evenly distributed on 2 to 4 foot spacings over the entire face. The slumps are 4 to 8 feet wide and display 6 to 8 inches of vertical displacement and 6 to 12 inches horizontal displacement. The tension cracks and slumps are evidently shallow features resulting from accelerated soil creep and small recumbent circular arc shear failures, respectively, in post-1962 fill that was sidecast down the face of the original 1952 and 1956 embankment without compaction or dressing. The estimated maximum depth of the recumbent slumps, based on headscarp to

toe bulge dimensions, is 5 to 6 feet. The downstream face of the post-1962 fill does not exhibit erosion and is sparsely vegetated with grass and thistles.

The downstream face of the 1952 embankment from station 10+55 to station 42+00 exhibits an occasional shallow soil detachment where sod has developed on the face and then detached. The shallow soil detachments are 4 to 6 inches deep and fail by shear parallel to the slope of the face.

The portion of the 1952 embankment between station 10+55 and station 21+81 exhibits a few erosional gulleys on the downstream face. The erosional gulleys are as much as 30 inches wide at their top edge and are cut 12 to 24 inches into the face. The gulleys are filled with cobbles and boulders. The gulleys may represent accelerated erosion, however, they appear to be "old" features and probably resulted from overtopping of the dam. There is no evidence of recent accelerated erosion anywhere on the dam and it is unlikely that precipitation runoff from the limited area of the crest would be sufficient to cause the erosion. Bill McCarter, the owner of the dams, cannot remember the exact circumstances that caused the gulleys.

2.3.2 Foundation Conditions, Seepage, and Drainage

The foundation of the dams, as previously described, consists of alluvial terrace deposits of silty clay, sand and gravel under most of the north embankment and black clay shale and some alluvium under the west embankment. The thickness of the alluvium and of the alluvial terrace deposits is unknown and foundation investigations were not conducted prior to construction of the dams. Bill McCarter describes a "deep" core trench excavated to a "heavy blue clay" under the portion of the embankment founded on alluvium between station 0+00 and 10+55. The core trench was backfilled with borrow from the left abutment.

Careful examination of the downstream face of the dams did not reveal evidence of free flowing seepage or of vegetation zoning or other features suggesting a wetting front or seepage surface. At the time of the inspection the north reservoir was at elevation 3100.0 feet and the west reservoir was at 3094.0 feet. Evidence of seepage was limited to the toe of the embankment and to the alluvial terrace foundation materials. The toe of the embankment from the outlet tube at about station 8+25 to station 9+30 displayed moist soil and relatively dense vegetation (grass) interpreted to be a wetting front. A corresponding area of the alluvial terrace foundation materials about 200 feet downstream from the toe of the embankment is the site of seepage from a gravelly sand lense. The seepage discharges on a terrace surface at about elevation 3085 above the right bank of the outlet tube channel. The estimated discharge of the free-flowing, clear, seepage was 20 to 40 gallons per minute. Standing water was present at another location in a cattail-filled slough downstream from the embankment at about station 31+50 and may be due to seepage through the alluvial foundation materials although no flow or current was evident in the standing water.

2.3.3 Stability

The information available regarding the McCarter Project is not sufficient to support an analytical evaluation of the embankment stability. There is no reliable information on strength and seepage characteristics of

the embankment or foundation materials. No piezometers are installed in the dams and the location of the seepage line is unknown. A review of all information pertaining to the McCarter Dams revealed no design seepage or stability analysis for the embankments. Discussion of embankment stability is therefore limited to observed conditions.

2.4 PROJECT OPERATION AND MAINTENANCE

2.4.1 Embankments

There is no periodic maintenance plan for the dams, however, the owner continually works on the dams as his time permits. At the time of the inspection he stated he was in the process of improving the riprap protection to the embankment and was also involved in incorporating a major pipe irrigation distribution system into the project.

2.4.2 Reservoir

The reservoir is operated with the low level outlets located at either embankment to control irrigation releases. The reservoir has a storage capacity of 7000 acre-feet and the owner allows it to fill during the off-irrigation season. He monitors the reservoir during spring runoff and regulates the pool to provide some flood control.

2.4.3 Warning Plan

There is no formal warning plan in use in the event of impending dam failure.

CHAPTER 3
FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dams, supplemented by analysis of the project in terms of the recommended guidelines, resulted in the following findings.

3.1.1 Size, Hazard Classification, and Safety Evaluation

The McCarter project impounds 7000 acre-feet of water with the reservoir at the crest of the dike embankment, elevation 3113 feet. In accordance with the recommended guidelines (Reference 1), the project is classified as intermediate in size and has a significant (category 2) downstream hazard potential rating. The recommended spillway design flood for this project is a 1/2 PMF. Because the project has no spillway and the outlet capacities are negligible compared to the PMF flood flows, the entire flood routing capabilities of the project lie in its ability to store the flood volume. Analysis indicates that a flood with 3% of the estimated PMF volume would just overtop the dams even if the reservoir was empty. Because the project is incapable of controlling one-half the PMF without overtopping and causing the embankment to fail, McCarter Dams do not conform to inspection guidelines.

3.1.2 Embankments

The McCarter Project consists of a 38-foot-high north embankment and an 28-foot-high west embankment connected by a continuous dike. The total embankment including dikes is 4200 feet long and consists of composite earthfill. The west embankment was constructed to its present height in 1952 and the north embankment was built to approximately the same elevation in 1953. In 1955 the north embankment was overtopped and failed and was repaired in 1956. The breach section was 100 to 200 feet wide with vertical walls and was repaired by laying back the vertical walls and placing earthfill in lifts aligned with the crest length. Some time after 1962 the north dam was raised 6 to 8 feet and a lower dike was constructed connecting to the west dike.

The north embankment is 2180 feet long including the dike and varies in elevation from 3115 feet NGVD to 3123 feet NGVD. The slopes of the embankment are approximately 1V on 1.4H and appear to represent the angle of repose of material side cast onto the slopes.

The soils used in the embankments all classify as heavy, plastic clay with minor amounts of silt, sand and rock fragments. The irregular grade of the embankment crest appears to be largely the result of the construction however some settlement has probably occurred as evidenced by the configuration of the outlet pipe. The surface of both embankments display shrinkage cracks due to dessication of the expansive clay soils. The inspection was conducted following a drier than normal summer and the shrinkage cracks probably swell shut when precipitation wets the soil.

The upstream slope of the north dam is protected with riprap of about 6 to 8 inches in average dimension which has been placed by dumping from the dam crest. A wave cut bench is present along the north embankment approximately 17 feet below the dam crest with a head scarp 4 to 6 feet high. Some newer riprap has been placed in the area of the scarp, however, it is not adequate to protect the embankment from continued wave erosion.

The downstream slope of the north dam exhibits occasional shallow cracks and slumps evidently resulting from accelerated soil creep and small recumbent slumps in fill side cast down the face of the embankment.

The west embankment is 2020 feet long including the dike and varies in elevation from 3113 feet, the lowest point on the embankment, to 3115.5 feet. The maximum height of the embankment is 30.5 feet and the slopes are approximately 1V on 1.4H. The faces are not dressed and the slopes appear to represent the angle of repose of embankment material side cast down the slope. The irregular grade appears to be largely the result of construction. The slopes are generally uniform and display some shrinkage cracks which are due to dessication of expansive clay soils. Shallow soil detachments are exhibited along the slopes where sod has developed and detached in recent years.

Careful examination of the downstream slopes of both embankments did not reveal evidence of seepage, vegetation zoning or other features suggesting a high pheatic surface. Evidence of seepage was limited to the toe of embankments and to the alluvial terrace foundation materials a short distance downstream of the embankment.

Conditions on the north and west dams and dikes indicate non conformance with recommended guidelines for stable earth embankments. Most of the observed conditions indicate questionable stability of the embankments: very steep slopes (angle of repose), tension cracks on embankment surface, sloughing of embankment material, possible evidence of foundation settlement, undetermined compaction of clayey fill and a lack of embankment zoning and drainage. Insufficient information is available to analytically evaluate embankment stability.

3.1.3 Spillway and Reservoir Capacity

The reservoir has a surface area of 960 acres and a storage capacity of 7000 acre-feet at the dike crest elevation 3113 feet NGVD. There is no spillway for the project. Storage at normal pool elevation 3100.0 feet is 1400 acre-feet.

Inspection guidelines (Reference 1) recommend that a dam of intermediate size with a significant downstream hazard potential be capable of safely handling a flood in the range of one-half to a full PMF. Because there are no inhabitable structures downstream, it is recommended that the dams safely pass the one-half PMF.

As shown on Plate 3, the north embankment is on the average of 8 to 10 feet higher than the dikes or the west embankment. A divide, which is approximately 2½ feet lower than the dike, separates the north and the west reservoir. The lowest point on the embankment is in the dike at this low

divide. During flood flows, water ponds to the top of the divide and transfers to the adjacent reservoir until there is a continuous water surface for both reservoirs. When the pool reaches elevation 3113 feet it will overtop the dike at approximately the divide between the reservoirs. Failure of the dike at this point could threaten the stability of the major embankments as it is uncertain which direction flow would take.

In 1955, when the north and west embankments were at the same elevation, the north embankment failed by overtopping when the low level outlet was inoperable. By Mr. McCarter's account the dam was overtopped at the outlet, washing out a section of embankment 100 to 200 feet wide. Mr. McCarter was away at the time and neighbors related to him that a wall of water progressed down Willow Creek to the highway at Galata. The water overtopped the highway bridge but did not wash it out. There was no damage to any buildings or residences by the flood wave. Mr. McCarter's house, located upstream of the highway bridge, is the lowest structure observed during the inspection being 5 to 10 feet higher than the highway. His house was not flooded by the dam failure flood wave in 1955.

An estimate of the PMF made during this dam safety analysis indicates that the dike embankment will be overtopped when approximately 3 percent of the PMF volume has entered the reservoir even if the reservoir was empty at the beginning of the storm. Since the reservoir is likely to contain some water before the occurrence of a probable maximum precipitation, overtopping of the embankment would occur at an even lesser percent of the PMF. Because the project has no spillway and the project cannot handle one-half of the PMF the project does not conform to inspection guidelines.

3.1.4 Outlet Works

An outlet is located in each embankment and allows the control of releases from the north reservoir (Willow Creek) and the west reservoir. The north outlet consists of a 170-foot-long, 60-inch-diameter corrugated metal pipe. The pipe is controlled by a slide gate mounted on the inlet structure. The gate is operated by a hand wheel mounted on the upstream slope of the dam. Controls for operating the gate may be inaccessible during high reservoir levels. The pipe is in good condition with minor seeps at approximately 4 joints. The pipe exits onto a concrete apron and discharges into the natural stream channel. The gate was not operated during the inspection. The inlet was not inspected except from inside the pipe and the gate was sealed and does not leak. The capacity of the outlet is 450 cfs.

The west outlet consists of a 66.5-foot-long, 84-inch-diameter, corrugated metal pipe located in the dike section of the embankment near the south abutment. The outlet is set high with the flow line 10 feet below the dam crest. Inflow to the pipe is regulated with an 84-inch-square, vertically mounted slide gate which was buried to within 3 feet of the top with silt. The owner said this is common and the silt flushes out with the first use. The outlet is also controlled at the downstream by a fabricated drop structure. The horizontal outlet pipe is capped on the end and an 84-inch-diameter hole cut into the bottom allows water to drop into a vertical pipe of the same diameter. Flow from the vertical pipe is controlled by a 30 x 72 inch hole cut in the side near the bottom and limits the capacity to 280 cfs.

Low level outlets are attended and operated on an as needed basis. During the irrigating season the project site is visited relatively routinely. However, during the rest of the year the project may not be visited for periods as long as two months.

3.2 RECOMMENDATIONS

Due to storage between normal pool and the dam crest, the present project provides a small degree of flood protection to the downstream area. The intent of report recommendations is to maintain or improve project safety, if feasible, without decreasing this flood protection.

The findings suggest that priority be given to the following recommendations:

1. Develop, implement and periodically test an emergency warning plan for use in the event of impending dam overtopping or structural failure.

2. Repair wave eroded scarps and protect the upstream embankment slopes with riprap.

3. Repair areas of gully erosion on downstream slopes.

4. Remove sediment from in front of the west outlet works and make the gate operational.

5. Repair holes in north dam outlet pipe which currently are exposing embankment material.

6. Evaluate the stability of the drop structure outlet in the west dam and provide for stability during full operation of the outlet during maximum reservoir elevations.

7. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and construct a spillway for the project as studies indicate.

8. Make an assessment of the phreatic surface through the dams and in the foundation by drilling and installing a few piezometers. Perform and place on file a slope stability analysis of the embankments. The analysis should be conducted by a qualified geotechnical engineer and be based on actual phreatic surface and strength characteristics as determined from piezometer drilling and sampling. Modify the dams as required for stability.

9. Engineers experienced in dam design and construction should inspect McCarter Dams at least once every five years.

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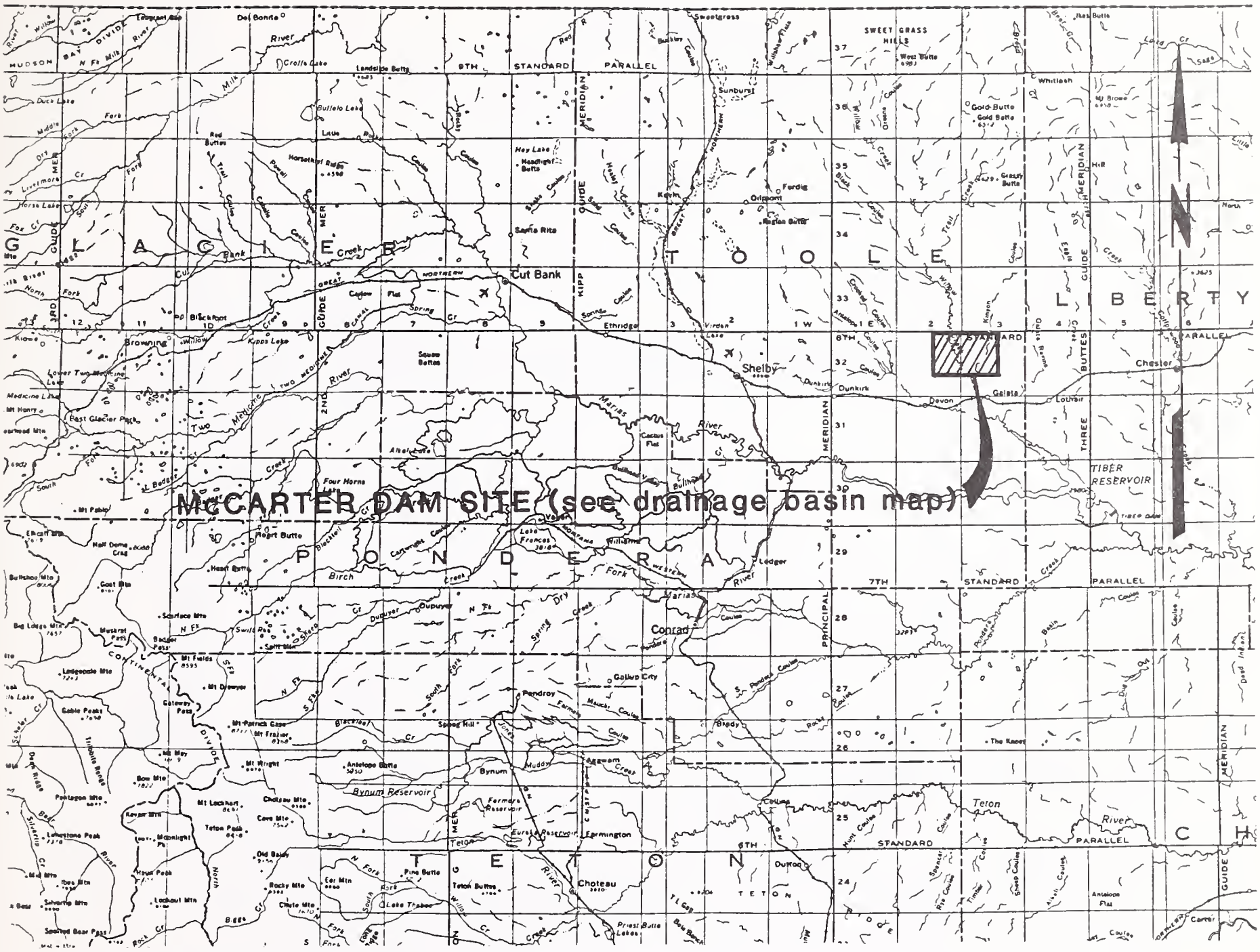
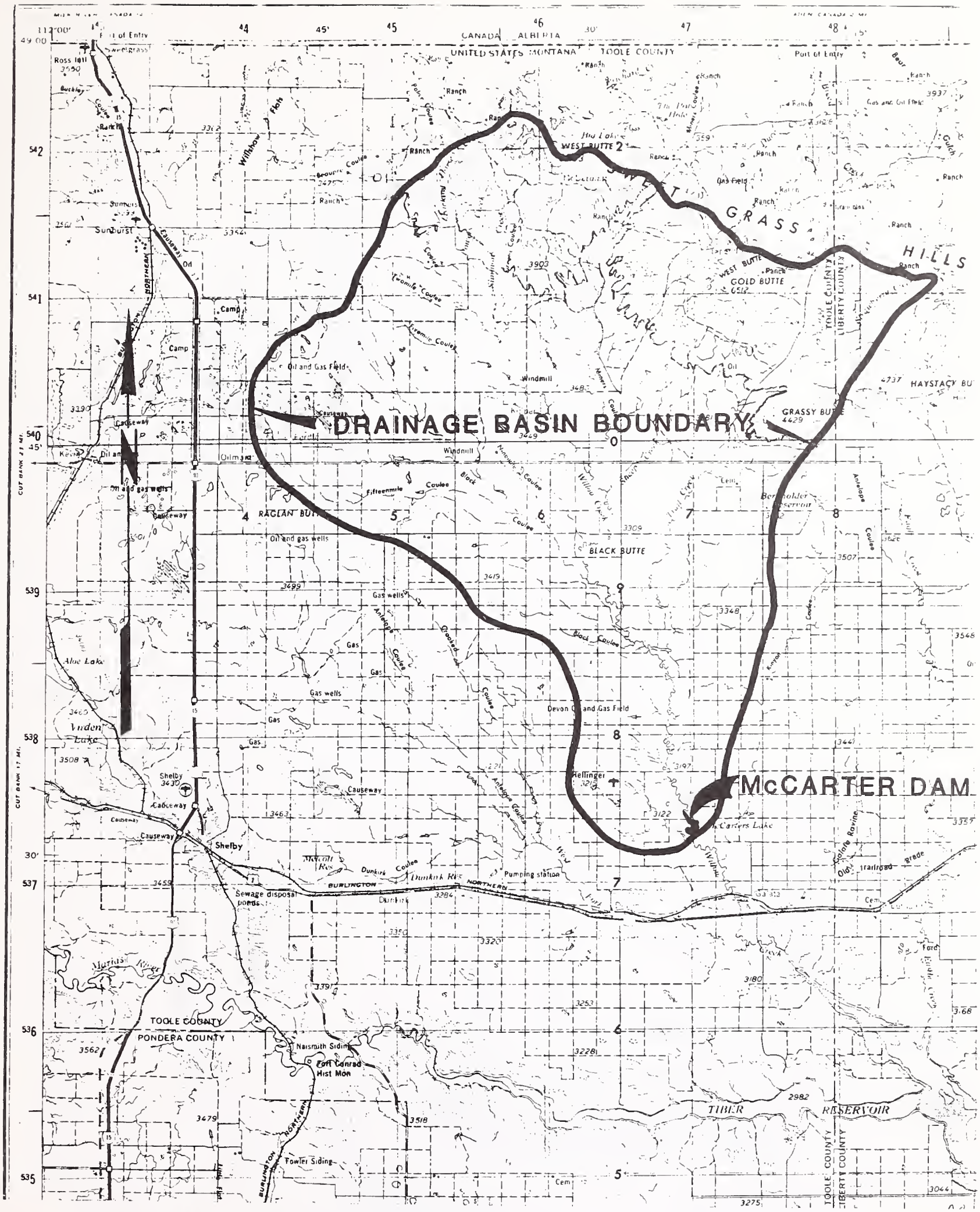

McCARTER DAM SITE (see drainage basin map)
GLACIER
TOOLE
LIBERTY
PONDERA
TETON
CHOUTEAU
Cut Bank
Shelby
Conrad
Choteau
Dutton
Chester
Devon
Dunkirk
Galata
Kevin
Sunburst
Sweetgrass
Fordyce
Oilmont
Ethridge
Virden
Browning
Kipp Lake
Two Medicine Lake
East Glacier Park
Lower Two Medicine Lake
Four Horns Lake
Lake Frances
Bynum
Bynum Reservoir
Farmers Reservoir
Eureka Reservoir
Farmington
Pendroy
Gallup City
Blackfeet
Blackfeet Cr
Teton River
Marias River
Two Medicine River
Dupuyer
Birch Creek
Spring Creek
Dry Creek
Muddy Creek
Willow Cr
Teton Buttes
Pine Butte
Lake Thibaudeau
Priest Butte Lakes
Bynum
Muddy
Agawam Creek
Choteau
Dutton
Bady
Sweet Grass Hills
West Butte
Gold Butte
Whitlash
Mt Brown
Grassy Butte
Sunburst
Kipp
Ethridge
Virden
Shelby
Dunkirk
Devon
Galata
Chester
Louisville
Conrad
Bynum
Choteau
Dutton
Bady
Pendroy
Gallup City
Farmington
Teton River
Marias River
Two Medicine River
Cut Bank
Blackfeet
Dupuyer
Birch Creek
Spring Creek
Muddy Creek
Willow Cr
Teton Buttes
Pine Butte
Lake Thibaudeau
Priest Butte Lakes
Bynum Reservoir
Farmers Reservoir
Eureka Reservoir
Farmington
Choteau
Dutton
Bady
Pendroy
Gallup City
Blackfeet
Blackfeet Cr
Teton River
Marias River
Two Medicine River
Cut Bank

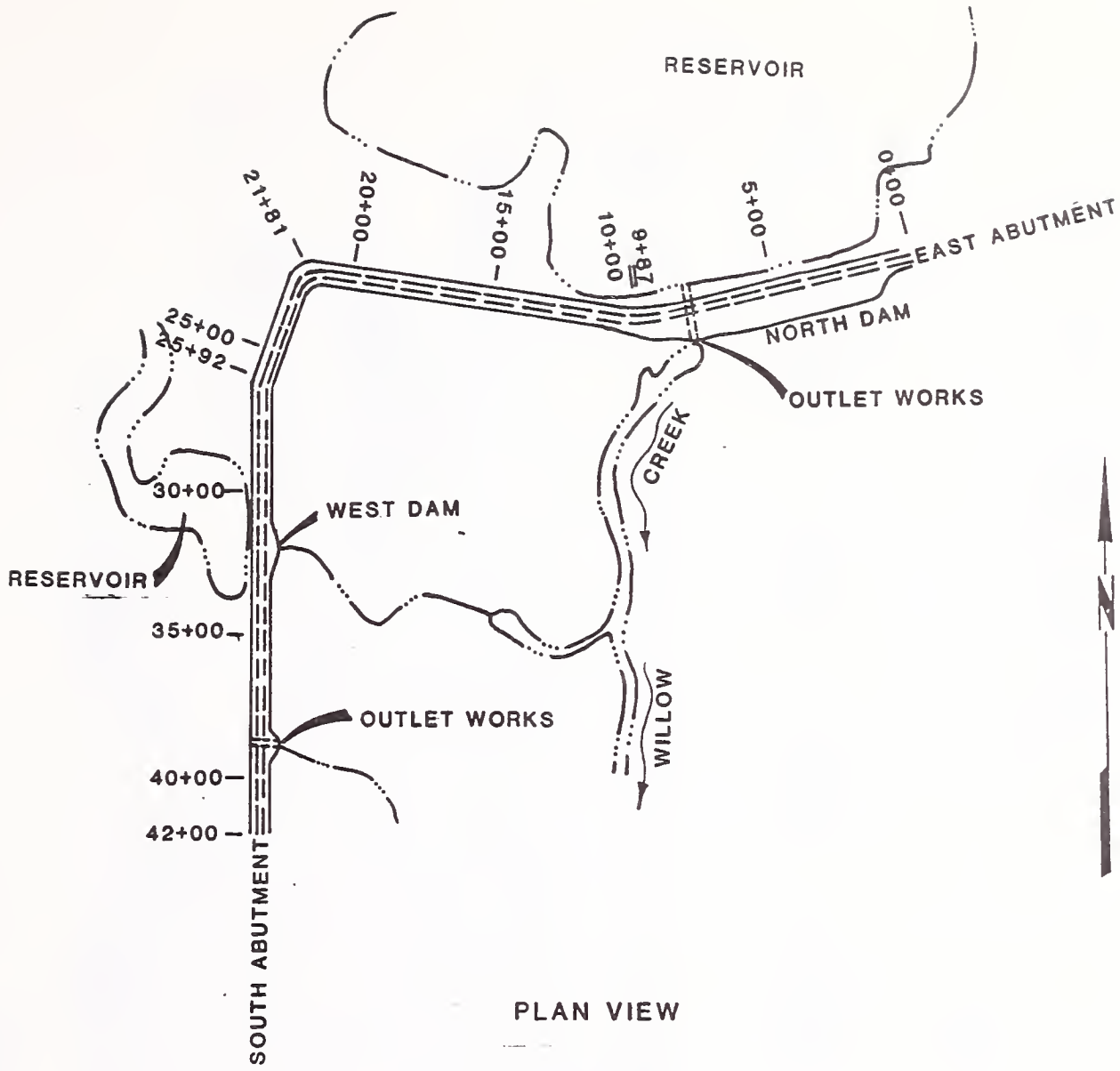


Source of Base: U.S. ARMY MAP SERVICE

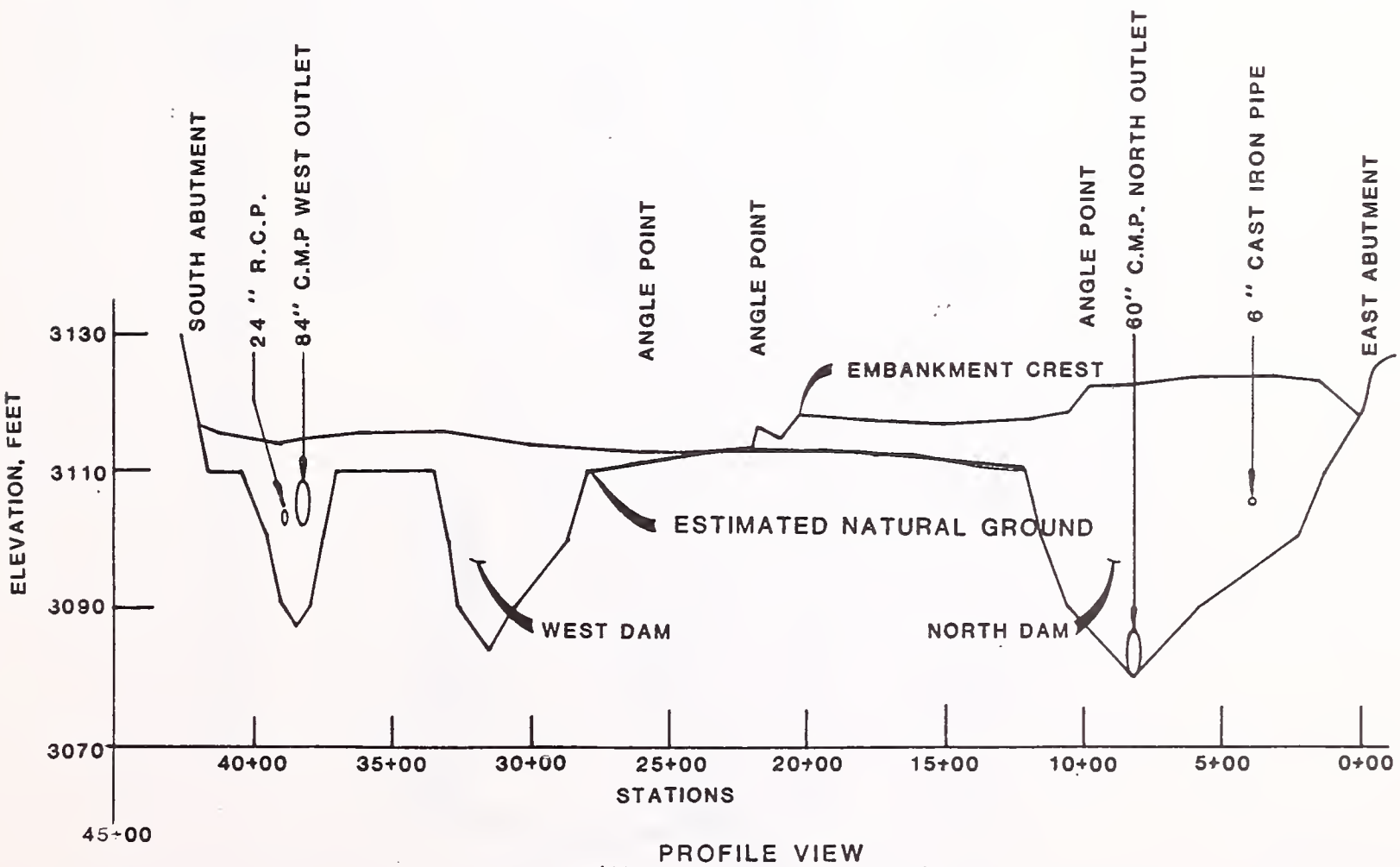
5 0 10

Scale in Miles

DRAINAGE BASIN MAP
PLATE 2

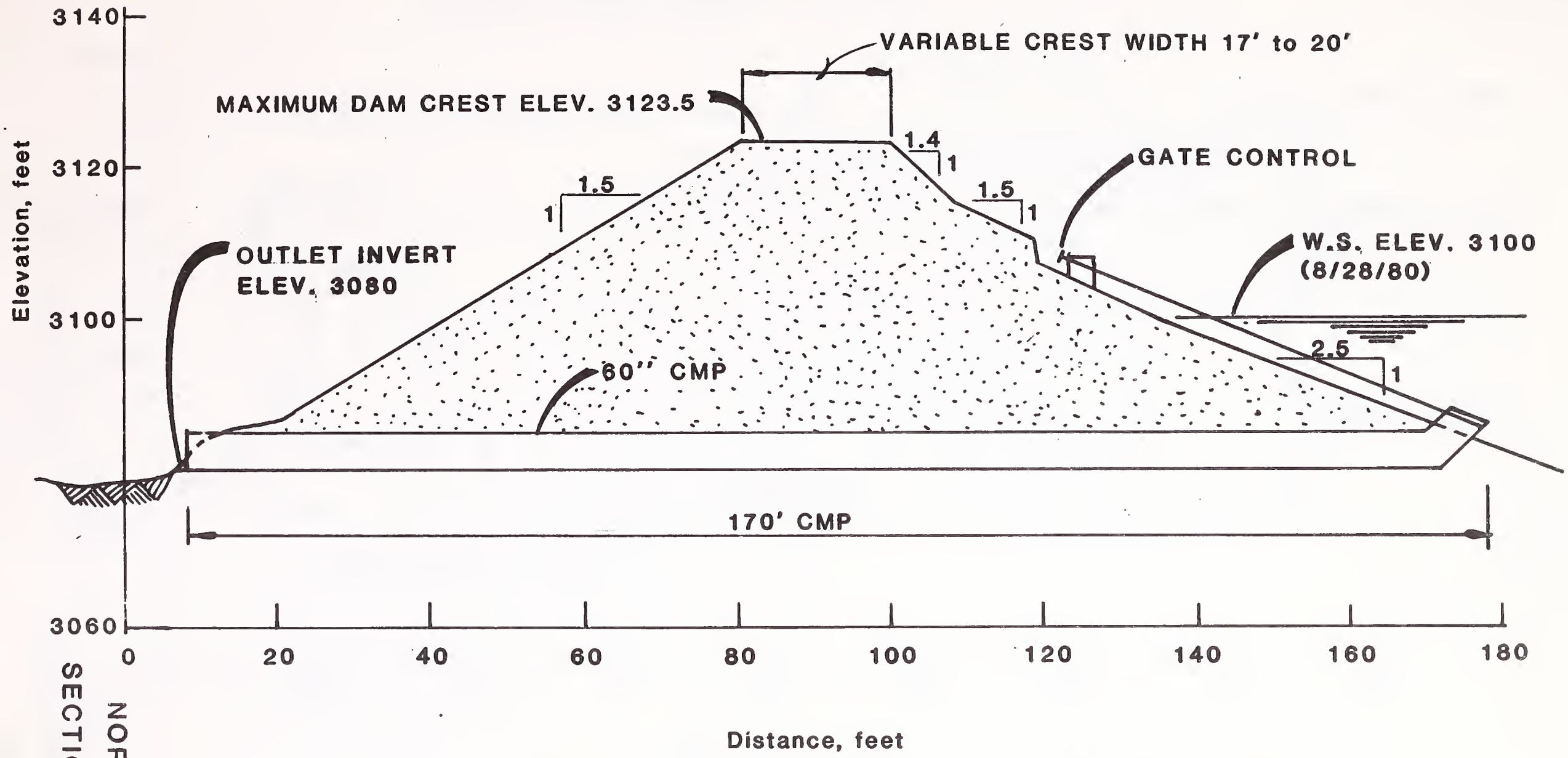


PLAN VIEW



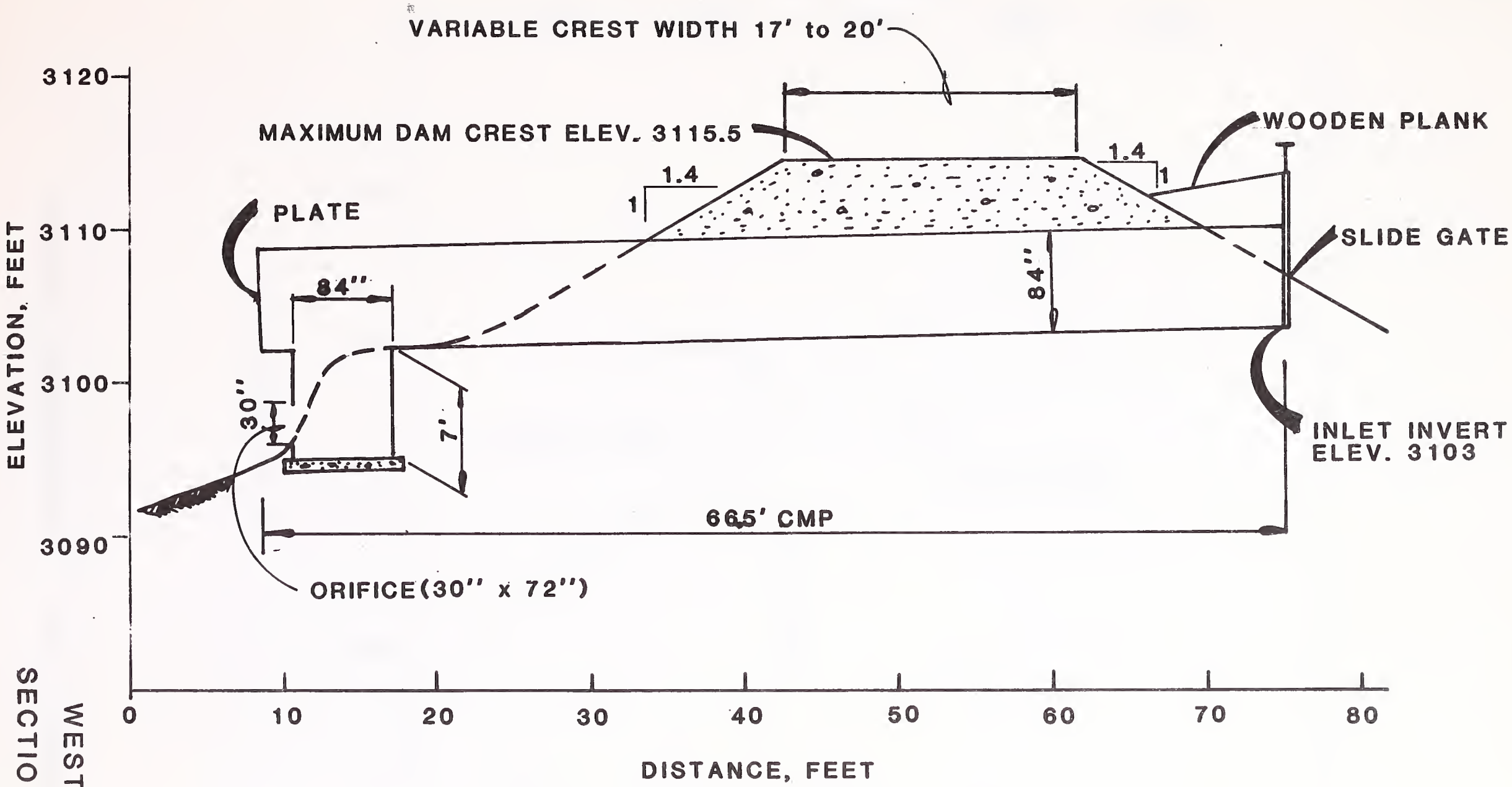
PROFILE VIEW
(Along ℄ of Dams and Dikes)

McCARTER RESERVOIR
PLAN AND PROFILE
PLATE 3



McCARTER
NORTH DAM CROSS
SECTION AND OUTLET

PLATE 4

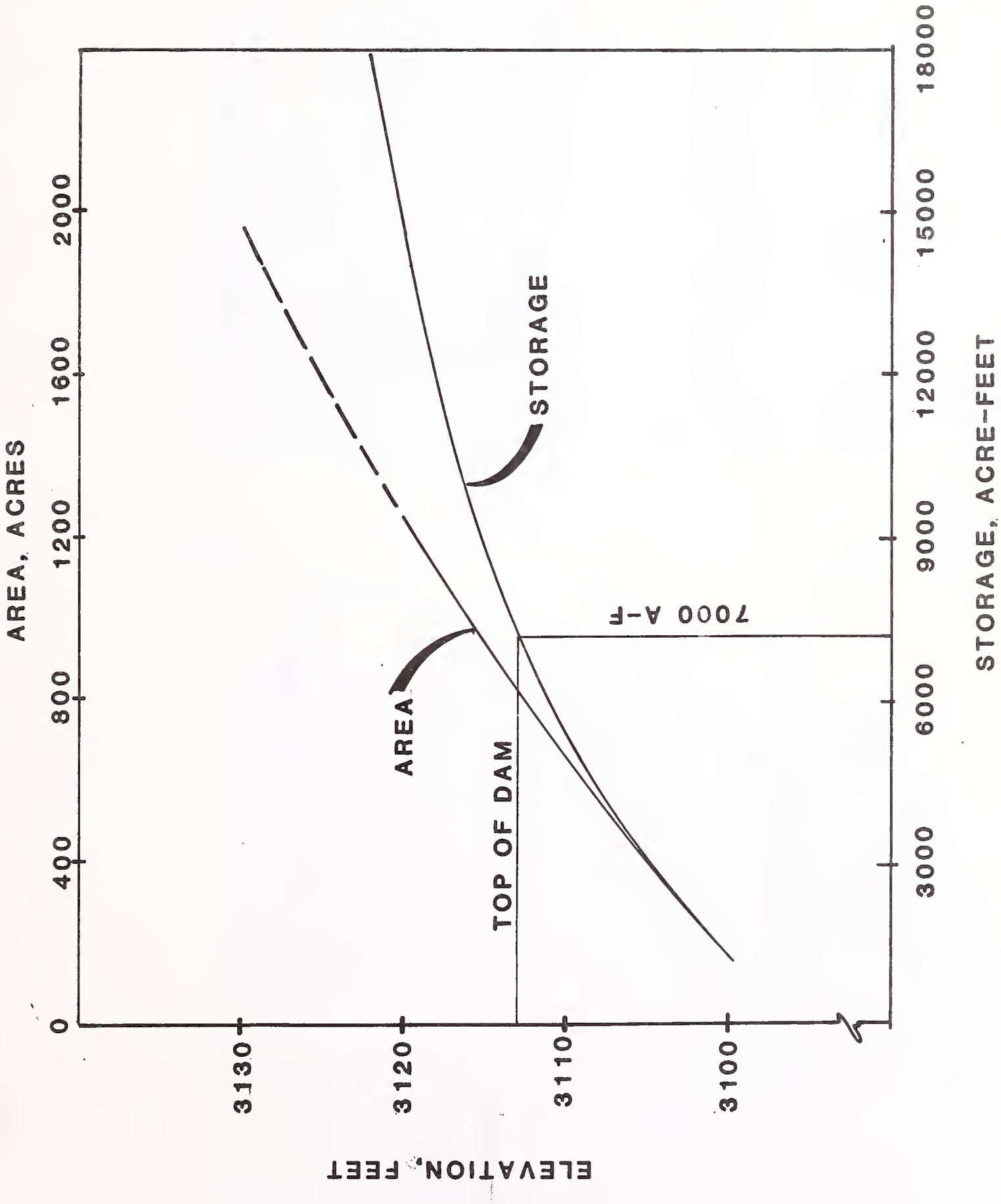


NOT TO SCALE
(slopes are approximate)

McCARTER

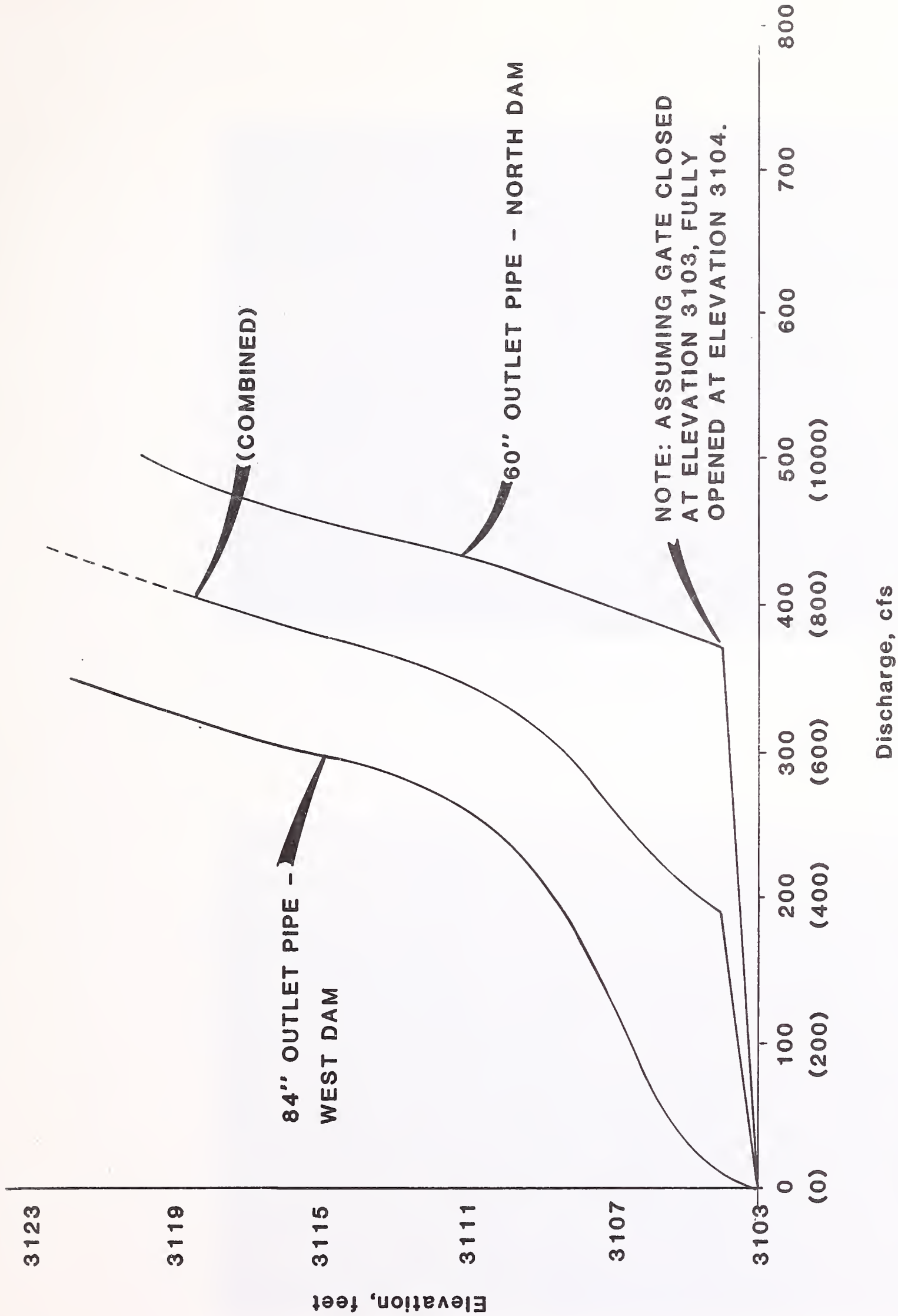
WEST DAM CROSS SECTION AND OUTLET

PLATE 5



McCARTER RESERVOIR AREA STORAGE CURVE

PLATE 6



McCARTER OUTLET RATING CURVES

PLATE 7

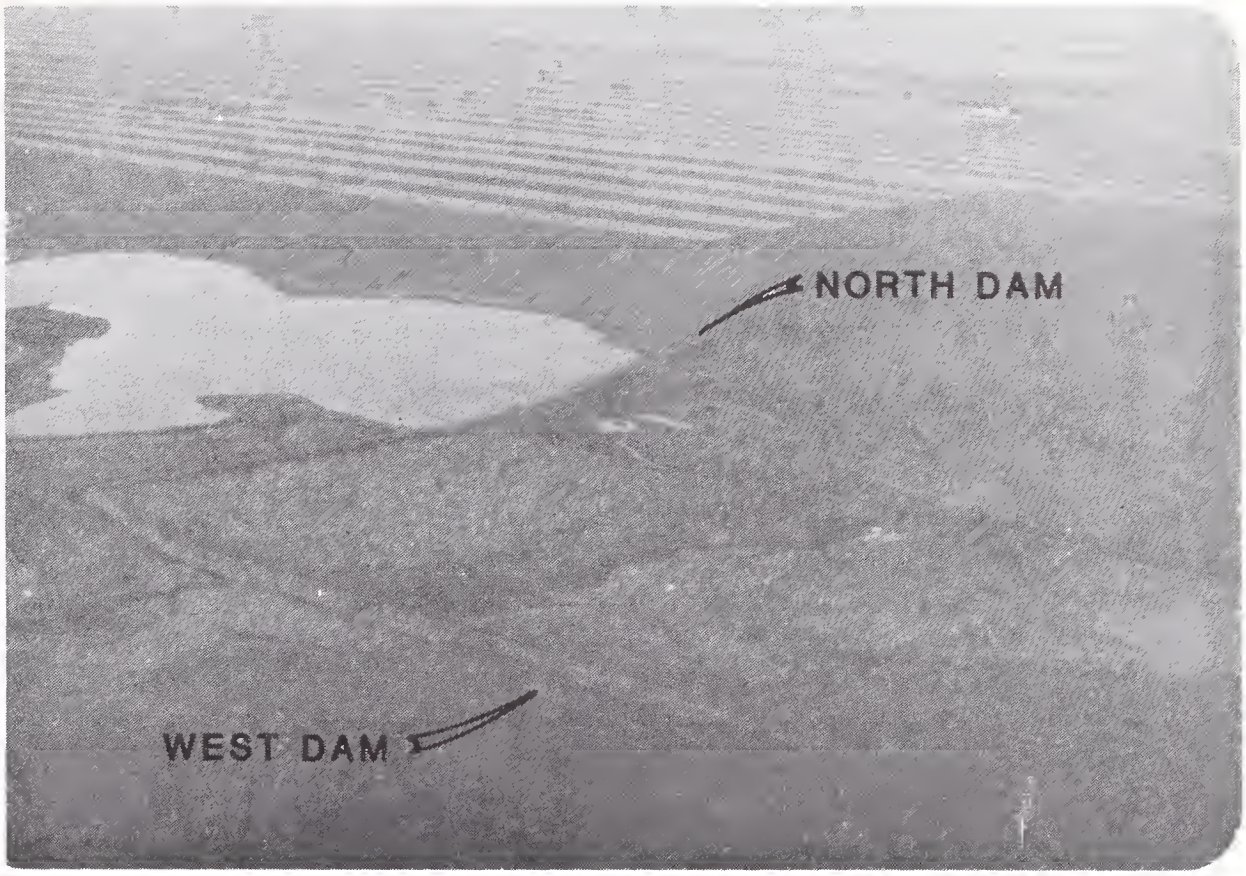


Photo 1 - Aerial View of McCarter Dam

Photo 2 - Aerial View of Town of Galata 3 miles Downstream from McCarter Dam

Photo 3 - North Dam Crest Taken from East Abutment

Photo 4 - Upstream Slope of North Dam Taken from East Abutment

Photo 5 - Downstream Slope of North Dam Taken from East Abutment

Photo 6 - Downstream Slope of North Dam Taken from West Abutment and Dike Area

Photo 7 - Tension Crack on Downstream Slope of North Dam

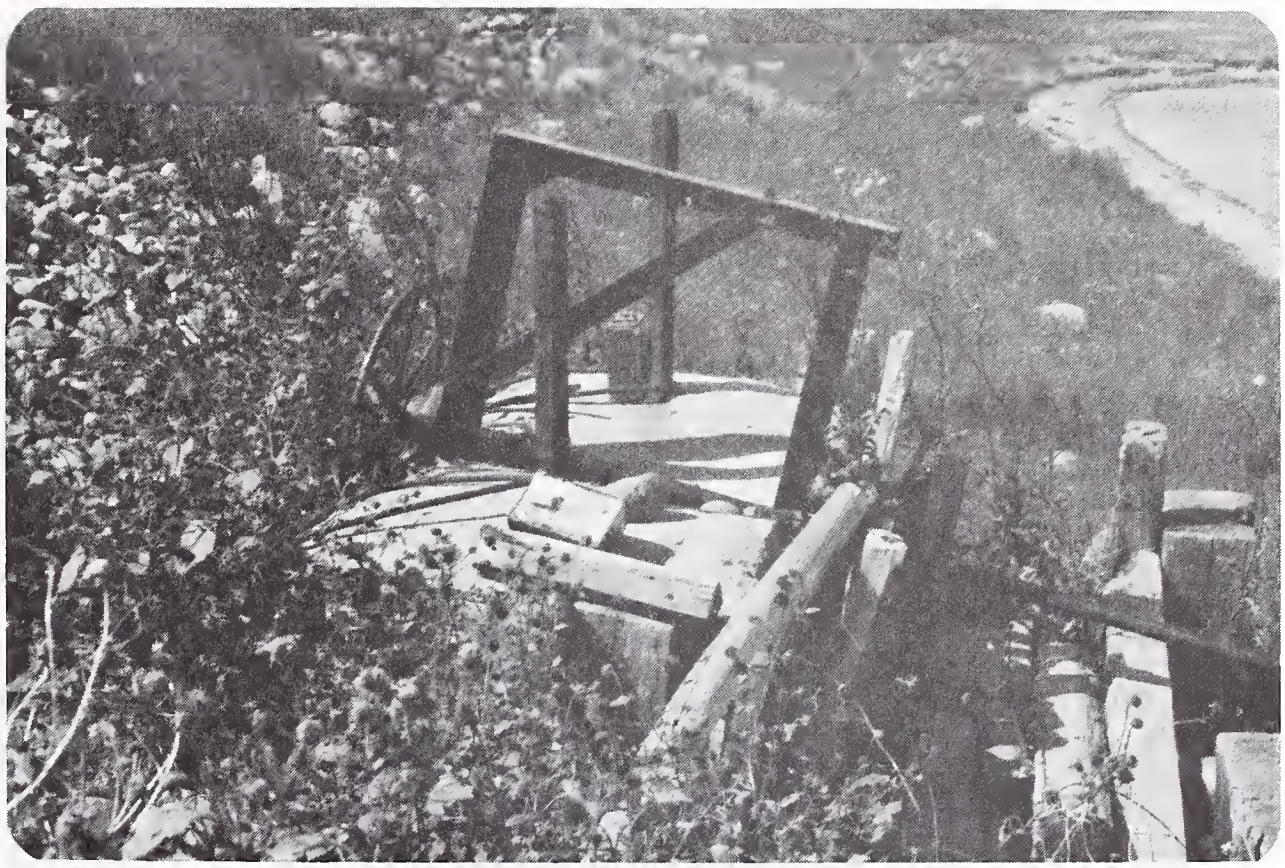


Photo 8 - Gate Control Wheel, North Outlet

Photo 9 - North Outlet Pipe, 60-inch Diameter

Photo 10 - Seepage in Inlet to North Outlet Works

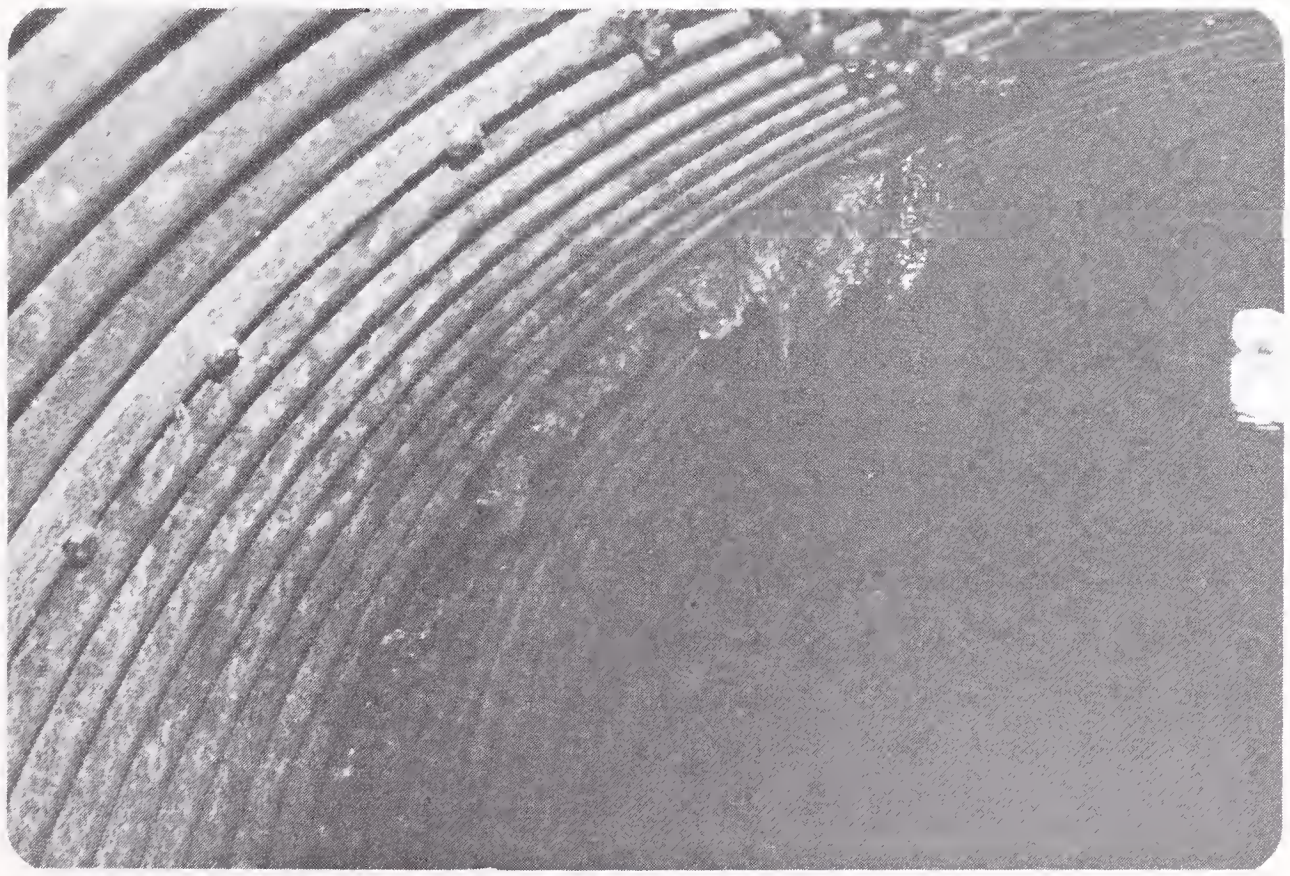


Photo 11 - Seepage in North Outlet Pipe

Photo 12 - Upstream Slope of West Dam Looking North

Photo 13 - Downstream Slope of West Dam Looking North

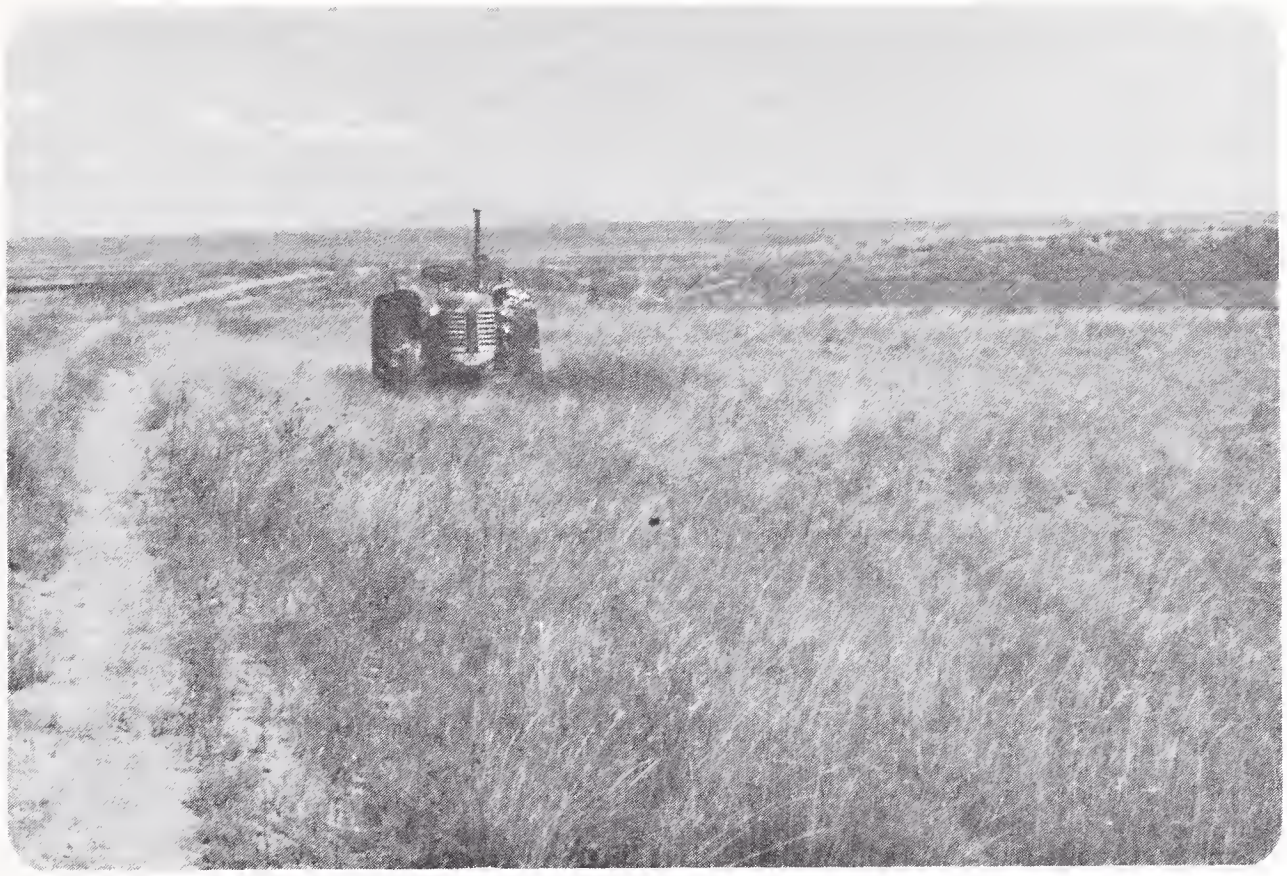


Photo 14 - Natural Ground Where West and North Dikes Meet, Station 21+81

Photo 15 - Upstream Slope of West Dike Looking South Toward 84-inch Outlet Gate

Photo 16 - West Outlet Pipe, 84-inch Diameter

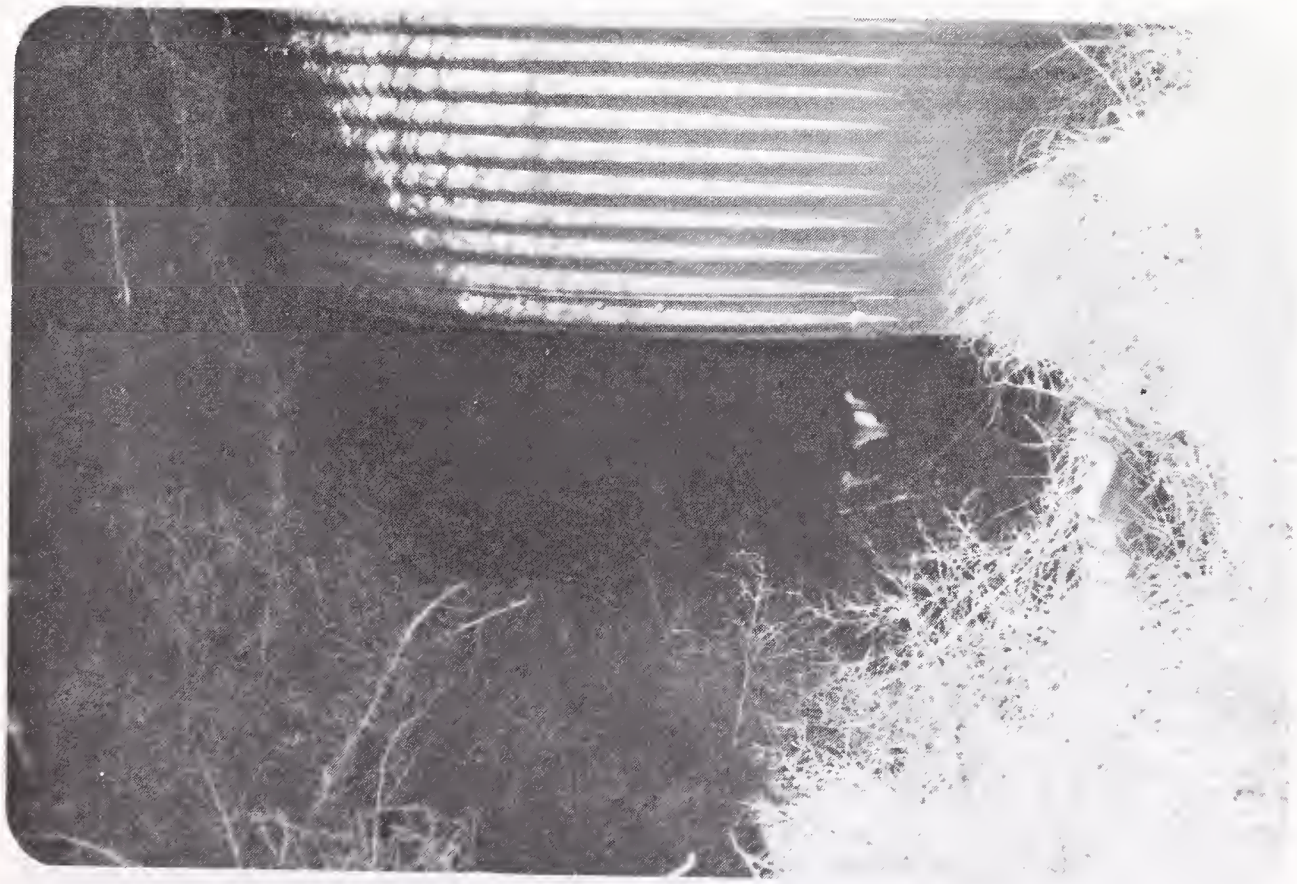


Photo 17 - Outlet Hole from Drop Structure at West Outlet Works

Photo 18 - Control Gate for 84-inch Diameter West Outlet Works

Photo 19 - Discharge Channel for West Outlets

Photo 20 - Control Gate for 24-inch Diameter Conduit Located 20 feet South of West Outlet Works

Photo 21 - Outlet of 24-inch Diameter Conduit in West Dike

APPENDIX

Correspondence

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

TED SCHWINDEN, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872 ADMINISTRATOR
(406) 449-3962 WATER RIGHTS BUREAU
(406) 449-2872 WATER SCIENCES BUREAU
(406) 449-2864 ENGINEERING BUREAU
(406) 449-2872 WATER PLANNING BUREAU

HELENA, MONTANA 59620

June 22, 1981

Ralph Morrison
Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Dear Mr. Morrison:

The Department of Natural Resources and Conservation has reviewed the final draft report on the McCarter Dams (MT-397) and (MT-390). We concur with the findings and recommendations in the report and feel that the report satisfies the criteria for the Phase I investigation. Our comments have been discussed with your staff and we understand that they will be incorporated into the final report.

Thank you for the opportunity to review and comment on the final draft report for this project.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau

RB:LT:lz

MORRISON-MAIERLE, INC.
QUALITY ASSURANCE

Project Manager

Branch Manager or Department Head

Peer Reviewer

Principal-In-Charge

Chief Engineer No.	Date Approved
81-14	7.23.81

Project No. 1447.009.06(33)